Spatial Coherence of Signals Forward Scattered from Sea Surface and Seabed In the East China Sea

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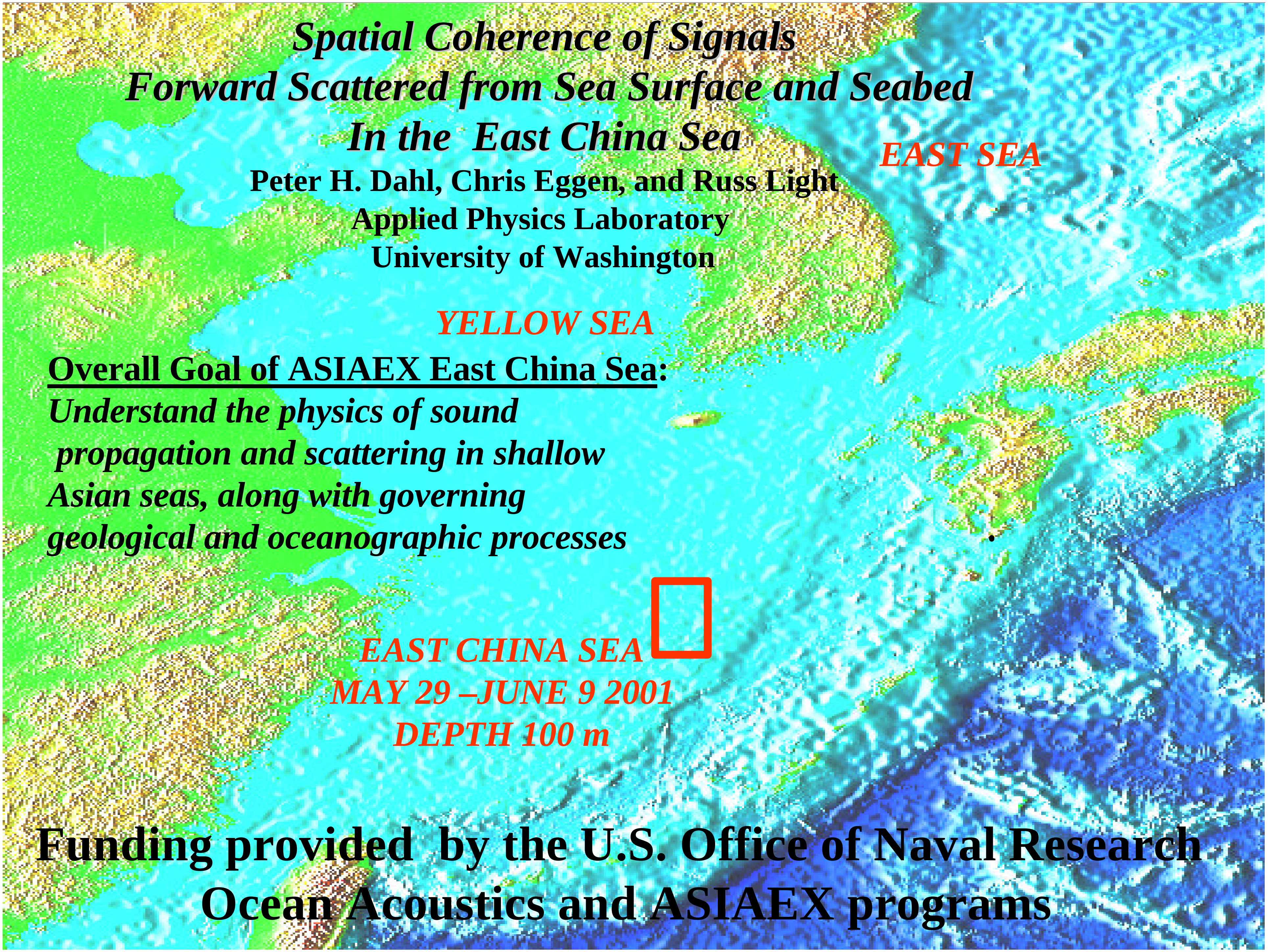


<u>Overall Goal of ASIAEX East China Sea</u>:
Understand the physics of sound propagation and scattering in shallow Asian seas, along with governing geological and oceanographic processes

Funding provided by the U.S. Office of Naval Research Ocean Acoustics and ASIAEX programs

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
09 JUN 2001	**N/A**	**-**

4. TITLE AND SUBTITLE	
Spatial Coherence of Signals Forward Scattered from Sea Surface and Seabed in the East China Sea	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Applied Physics Laboratory, University of Washington**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
Also See: M001452, The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**28**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

RESEARCH OBJECTIVES

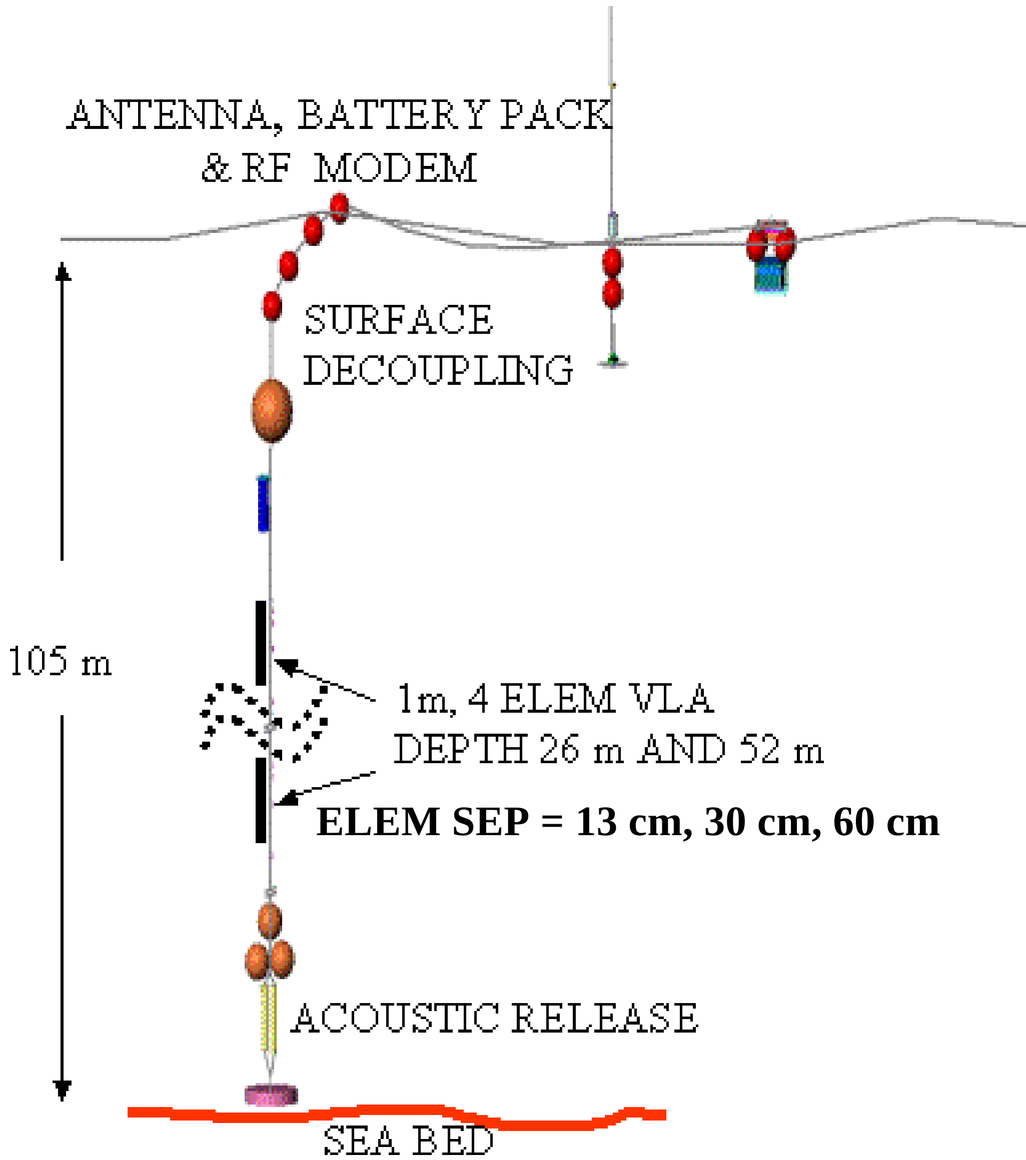
A. Understand behavior of vertical coherence in sea surface scattering, and its relation to:

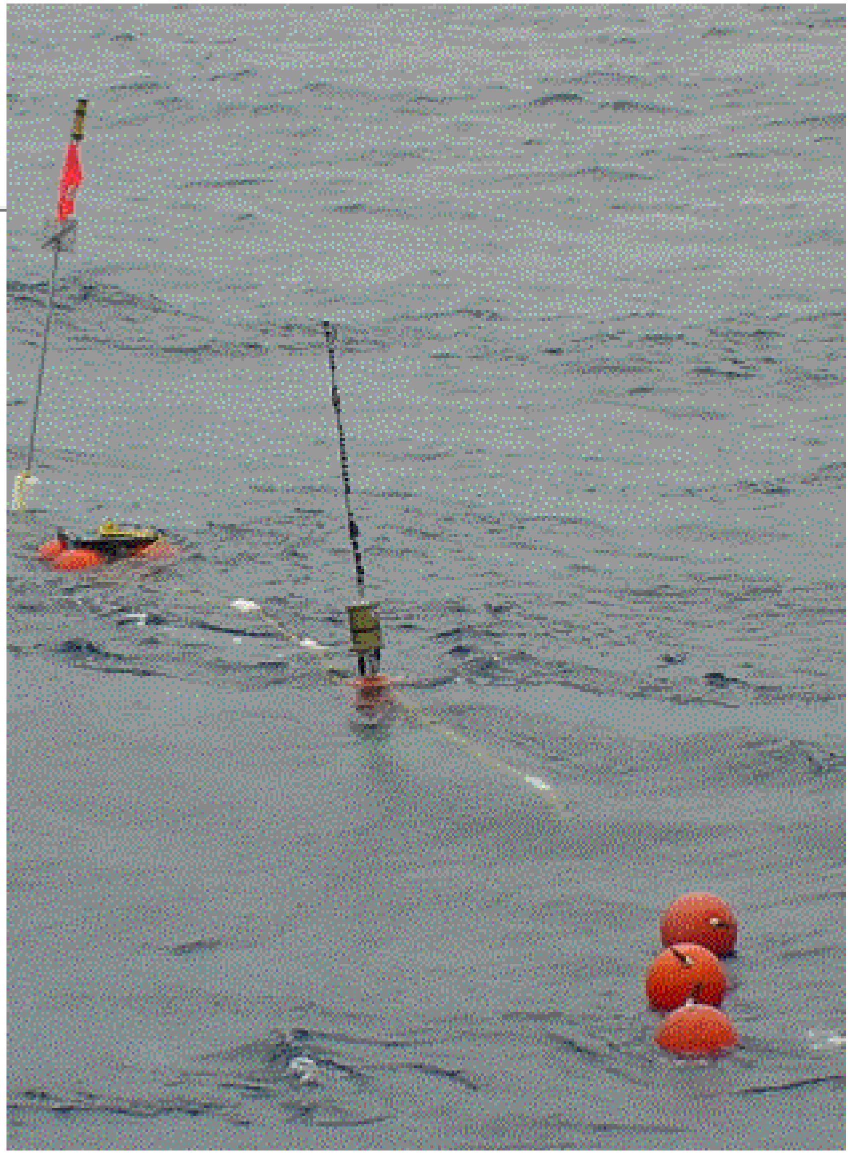
- ***sea surface bistatic cross section***
- ***horizontal coherence***
- ***wind speed, sea state, wave directionality***
- ***frequency***
- ***acquisition geometry***
- ***sound speed profile***

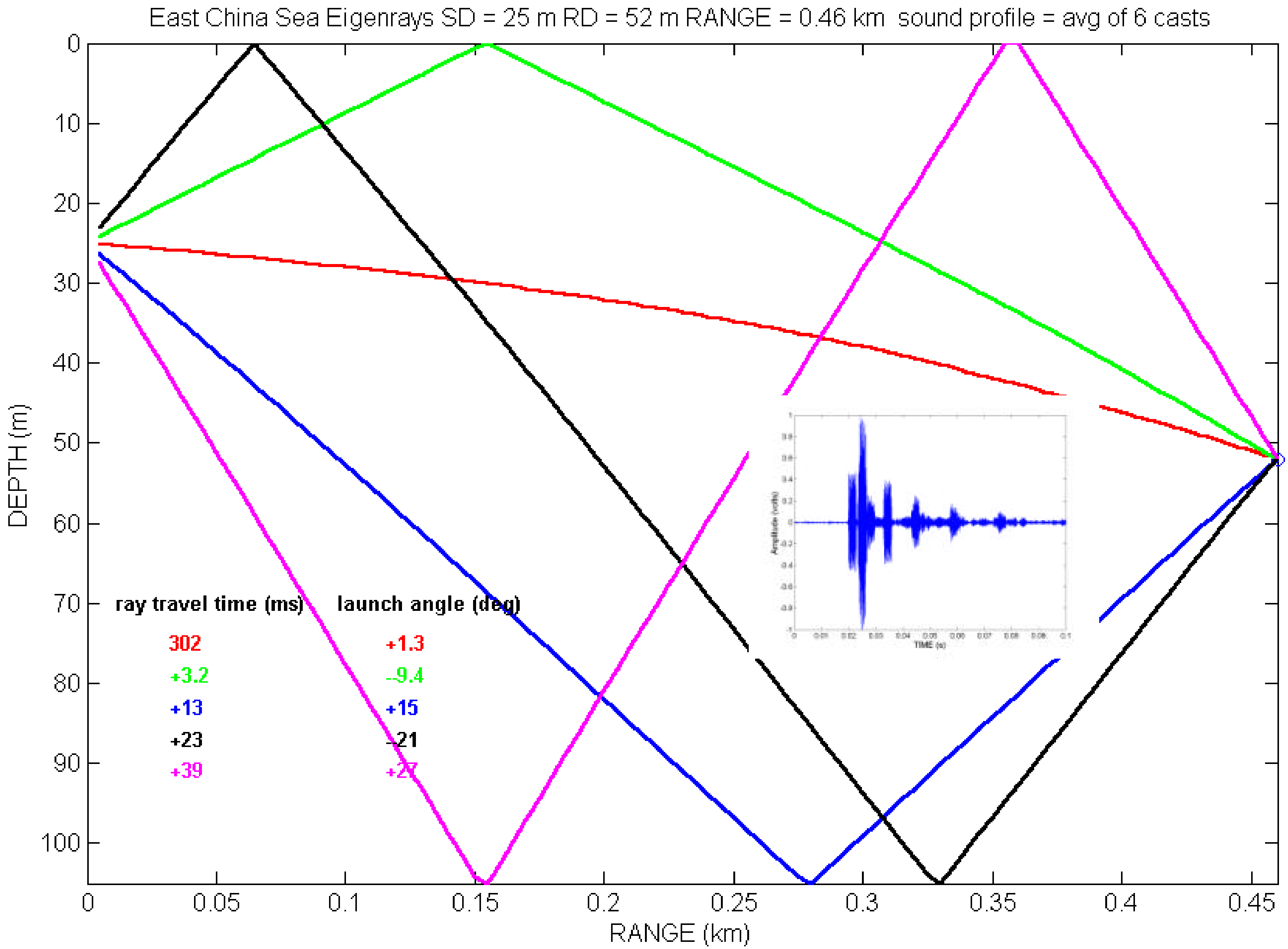
B. Sea bed reflection (2-8 kHz)

- ***what are bottom losses versus grazing angle, and are they consistent with inversions?***

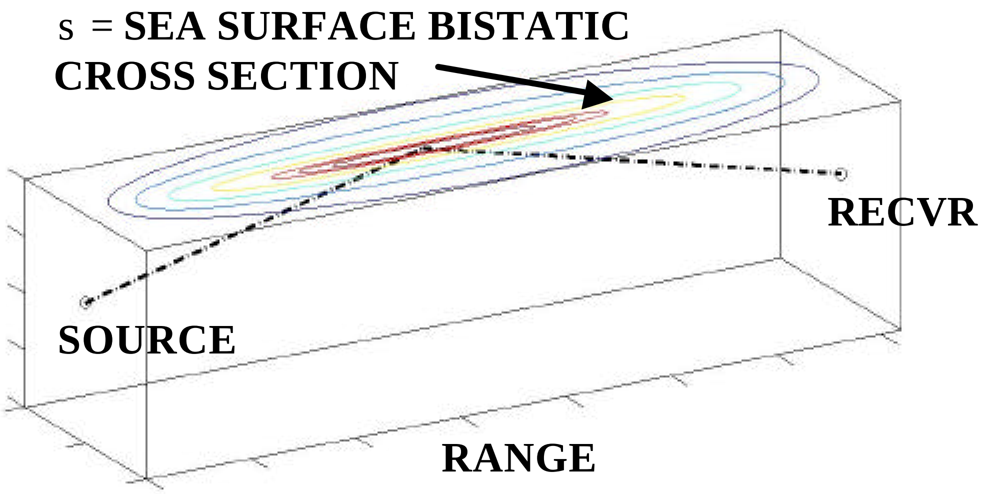
SOUND RECEIVER ARRAY







East China Sea Eigenrays SD = 25 m RD = 52 m RANGE = 0.46 km sound profile = avg of 6 casts
DEPTH (m)
RANGE (km)
ray travel time (ms)
launch angle (deg)
302
+1.3
+3.2
-9.4
+13
+15
+23
-21
+39
+27
TIME (s)



$$s \propto \iint e^{2ik(ax+bz)} e^{-?^2 \underbrace{[1-C(x,z)]}_{}} dxdz$$

ENVIRONMENTAL DEPENDENCE EMBODIED HERE

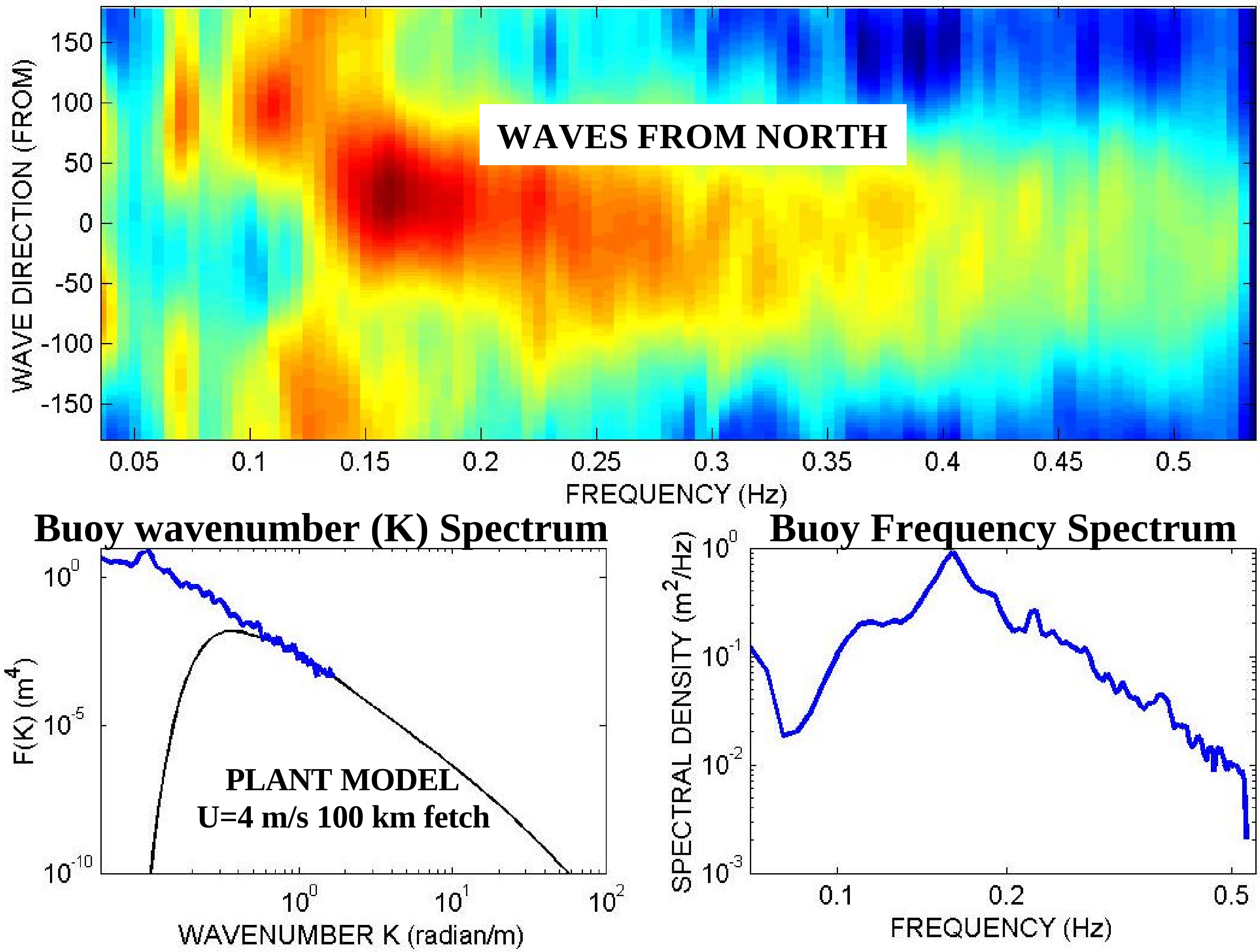
$$c = kH(sinq_i + sinq_s)$$ **ROUGHNESS PARAMETER, FUNCTION OF k H INCIDENT AND SCATTERED ANGLES**

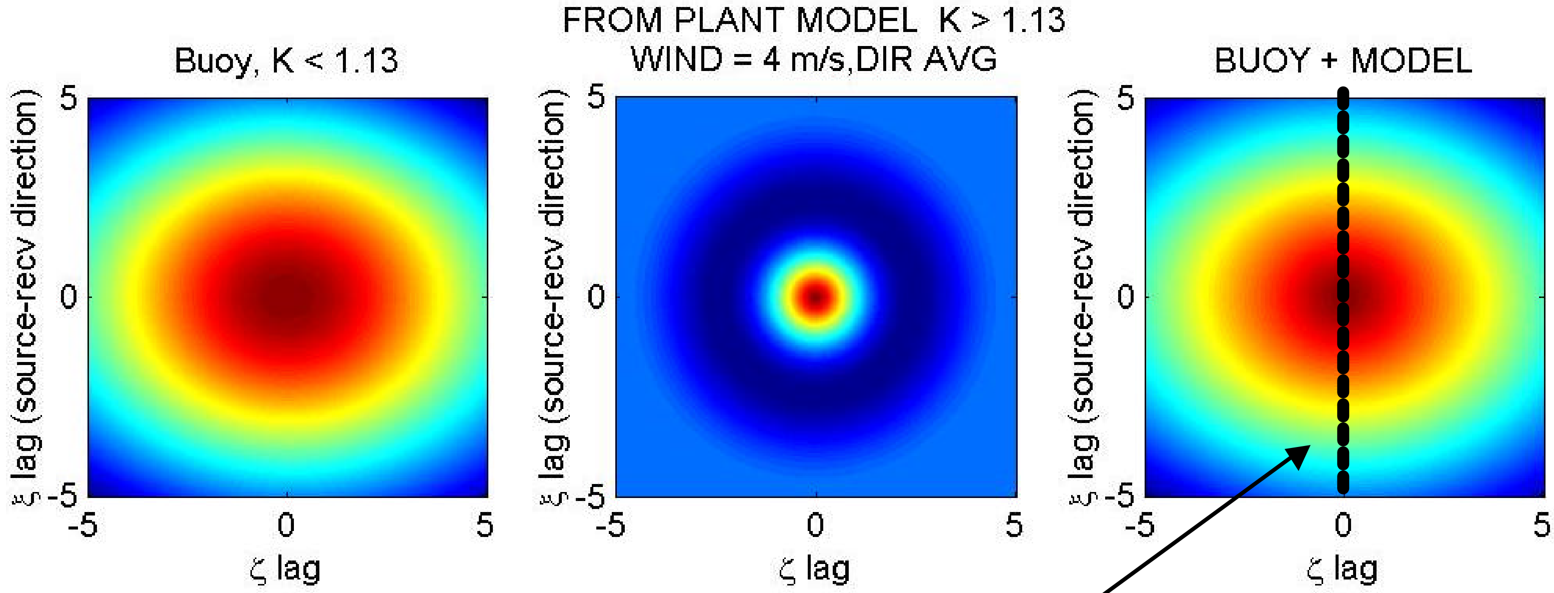
$$C(x,z)$$ **2D SEA SURFACE CORRELATION FUNCTION**

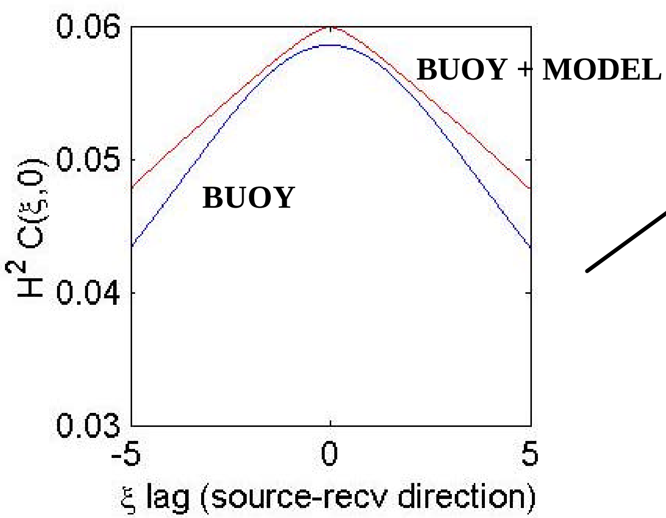
Sea surface bistatic cross section computed via the small slope approximation. Wave buoy data + wave model (Plant 2002) used for required sea surface correlation function


ENVIRONMENTAL ACOUSTIC MEASUREMENTS:
DIRECTIONAL WAVE BUOY
directional wave spectra every 0.5 h 28 May – 8 June
waveheight variance spectra
0.03 - 0.64 Hz, 0.005 Hz bins
3-deg directional bins
20 min averaging period

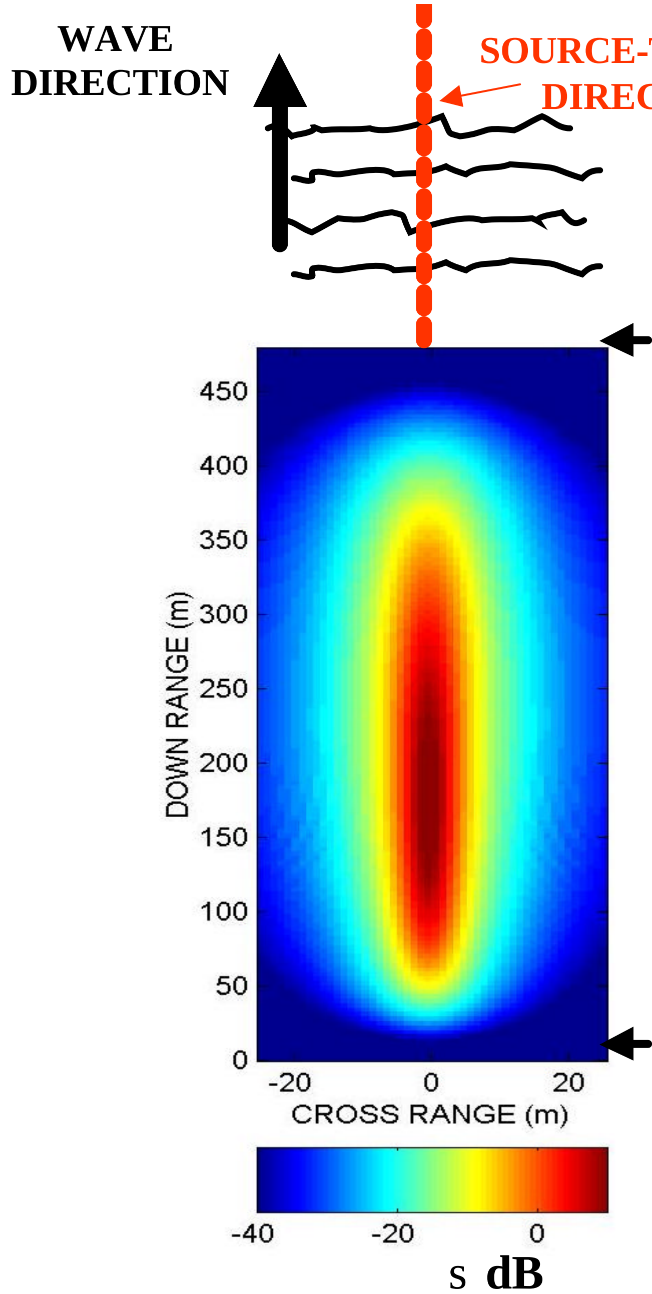
RAW DIRECTIONAL WAVE SPECTRUM FROM BUOY, RUN 22







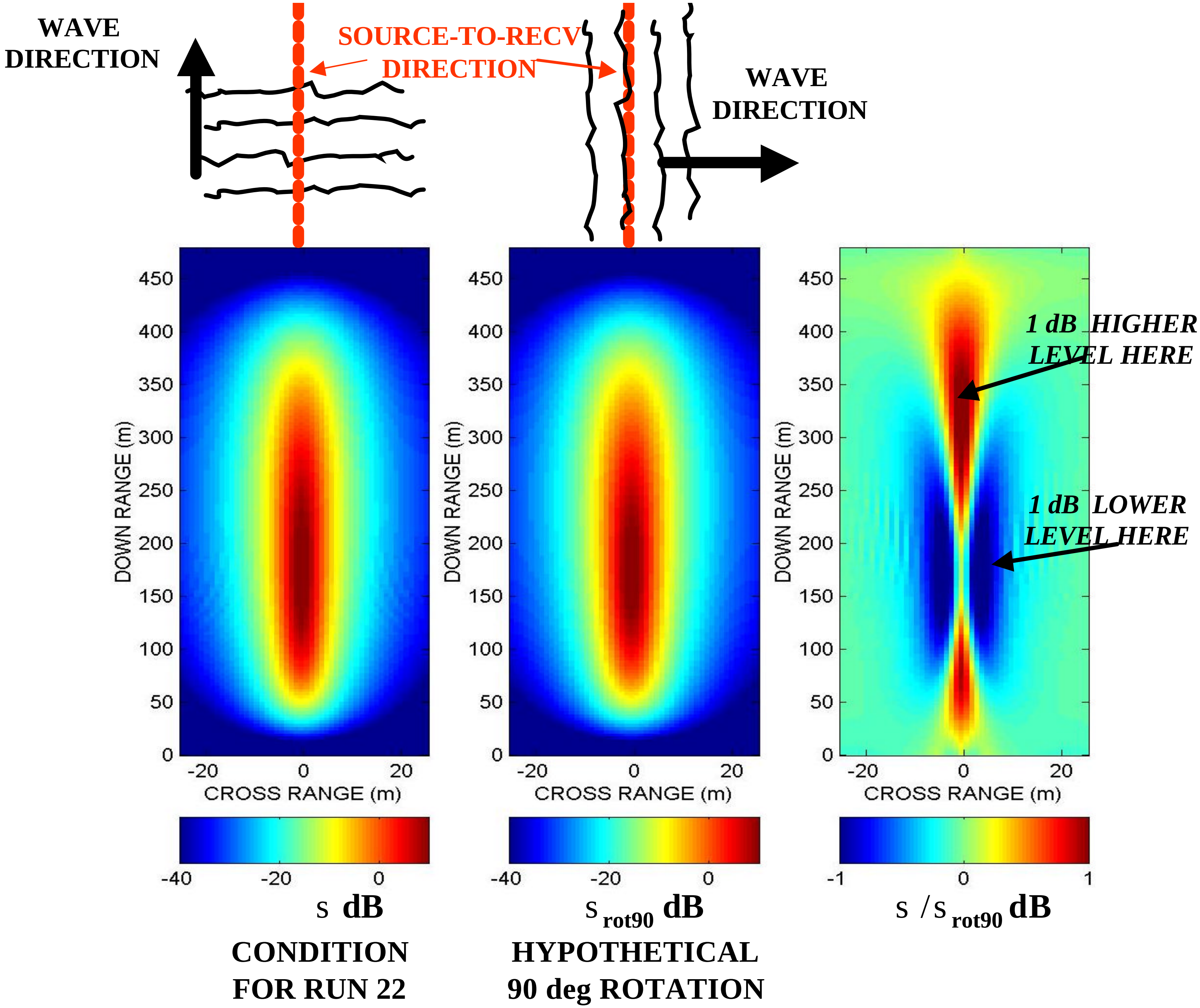
A CUT DOWN THE IN-PLANE AXIS OR SOURCE-RECEIVER DIRECTION



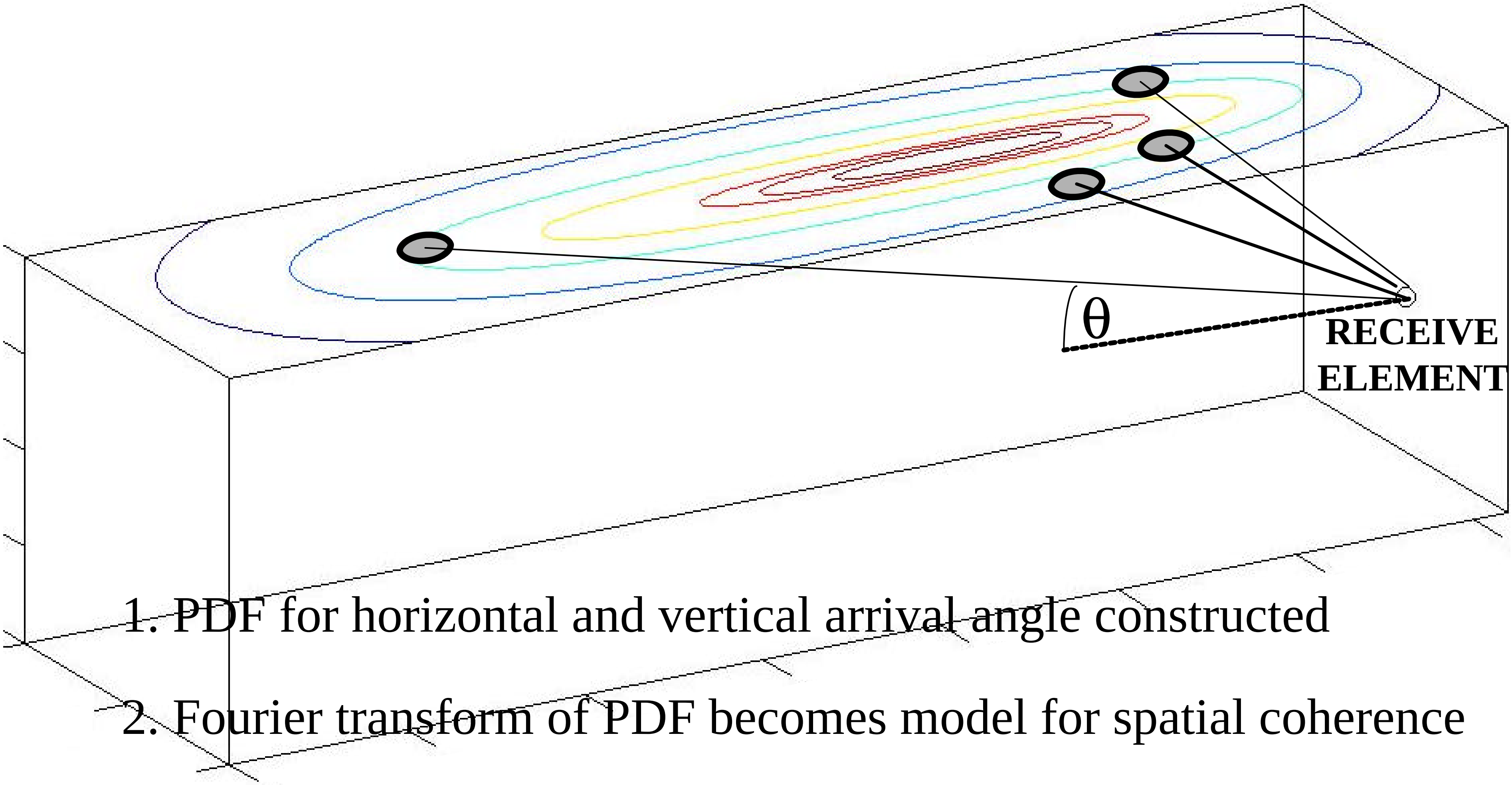
Receiver: depth 52 m, at range 460 m

“TOP VIEW” or “MAP” of s over the sea surface

Source: depth 25 m


WAVE DIRECTION
SOURCE-TO-RECV DIRECTION
WAVE DIRECTION
450
400
350
300
250
200
150
100
50
0
DOWN RANGE (m)
-20
0
20
CROSS RANGE (m)
1 dB HIGHER LEVEL HERE
1 dB LOWER LEVEL HERE
-40
-20
0
-1
0
1
S dB
S rot90 dB
S / S rot90 dB
CONDITION FOR RUN 22
HYPOTHETICAL 90 deg ROTATION

INTENSITY VS VERTICAL ARRIVAL ANGLE q

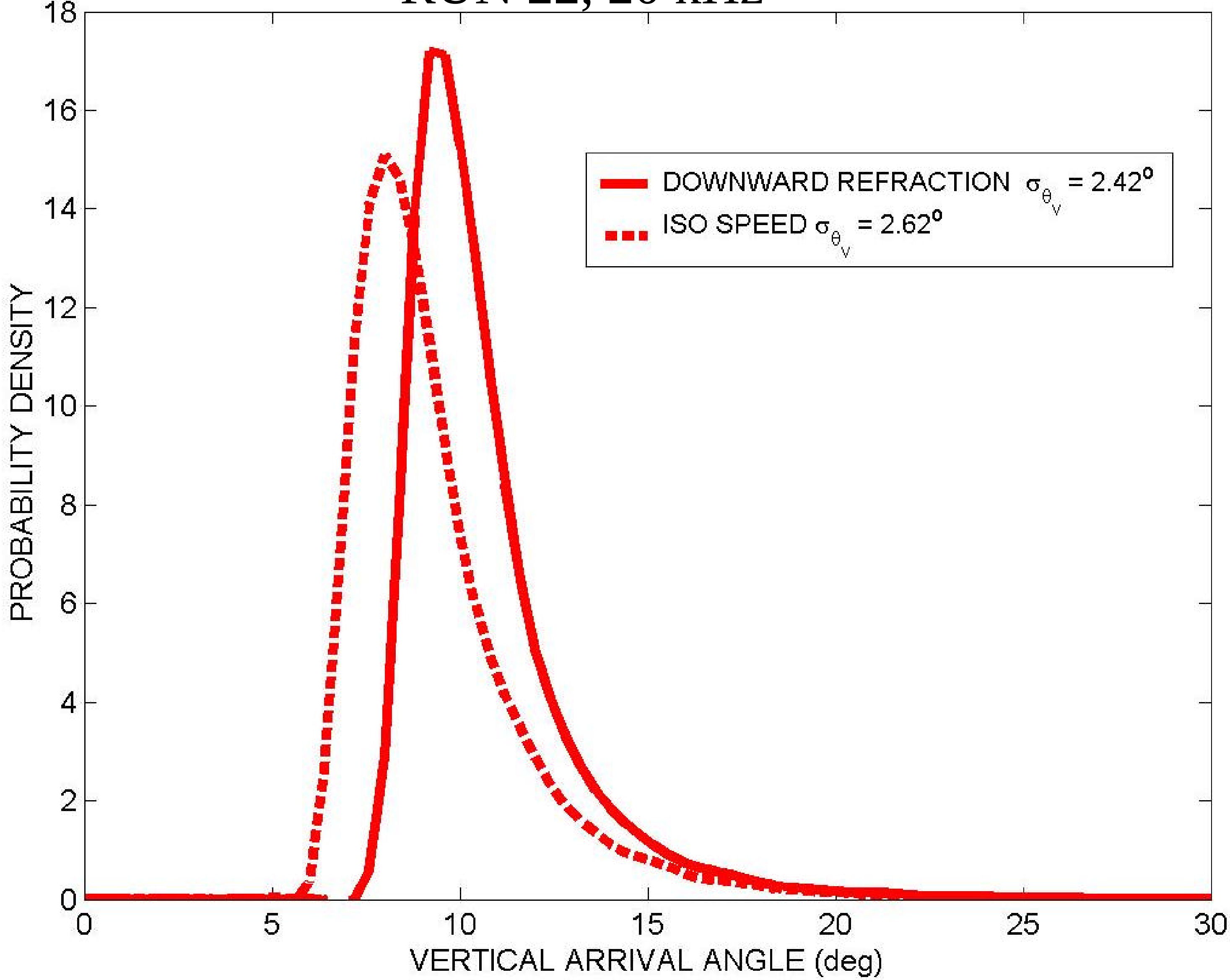


1. PDF for horizontal and vertical arrival angle constructed

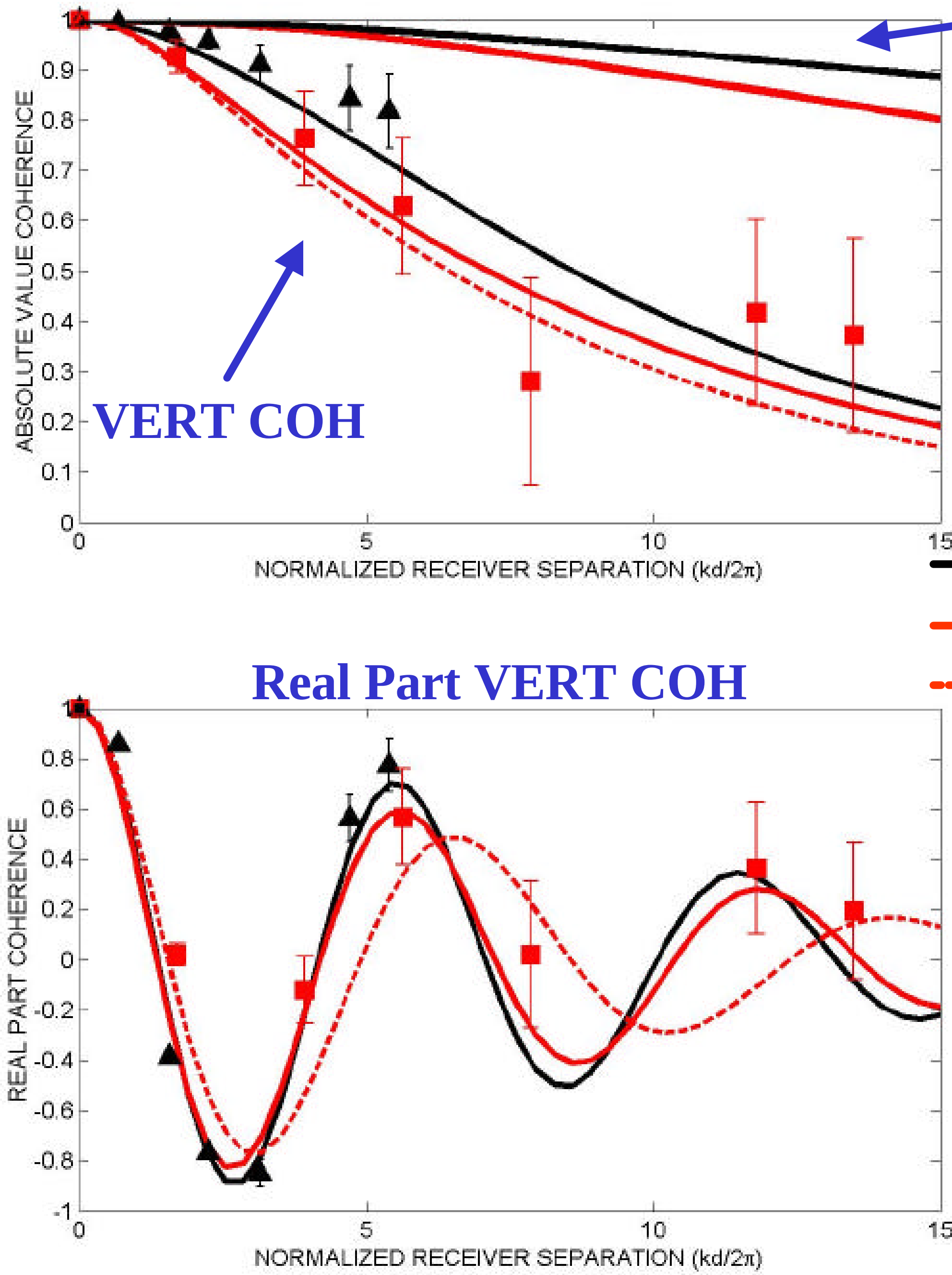
2. Fourier transform of PDF becomes model for spatial coherence

Dahl P. H., *J. Acoust. Soc. Am.*, 1996, 1999;
***J. Oceanic Eng.*, 2001**

RUN 22, 20 kHz



DOWNWARD REFRACTION σ_{θ_V} = 2.42°
ISO SPEED σ_{θ_V} = 2.62°
PROBABILITY DENSITY
VERTICAL ARRIVAL ANGLE (deg)
0
2
4
6
8
10
12
14
16
18
0
5
10
15
20
25
30

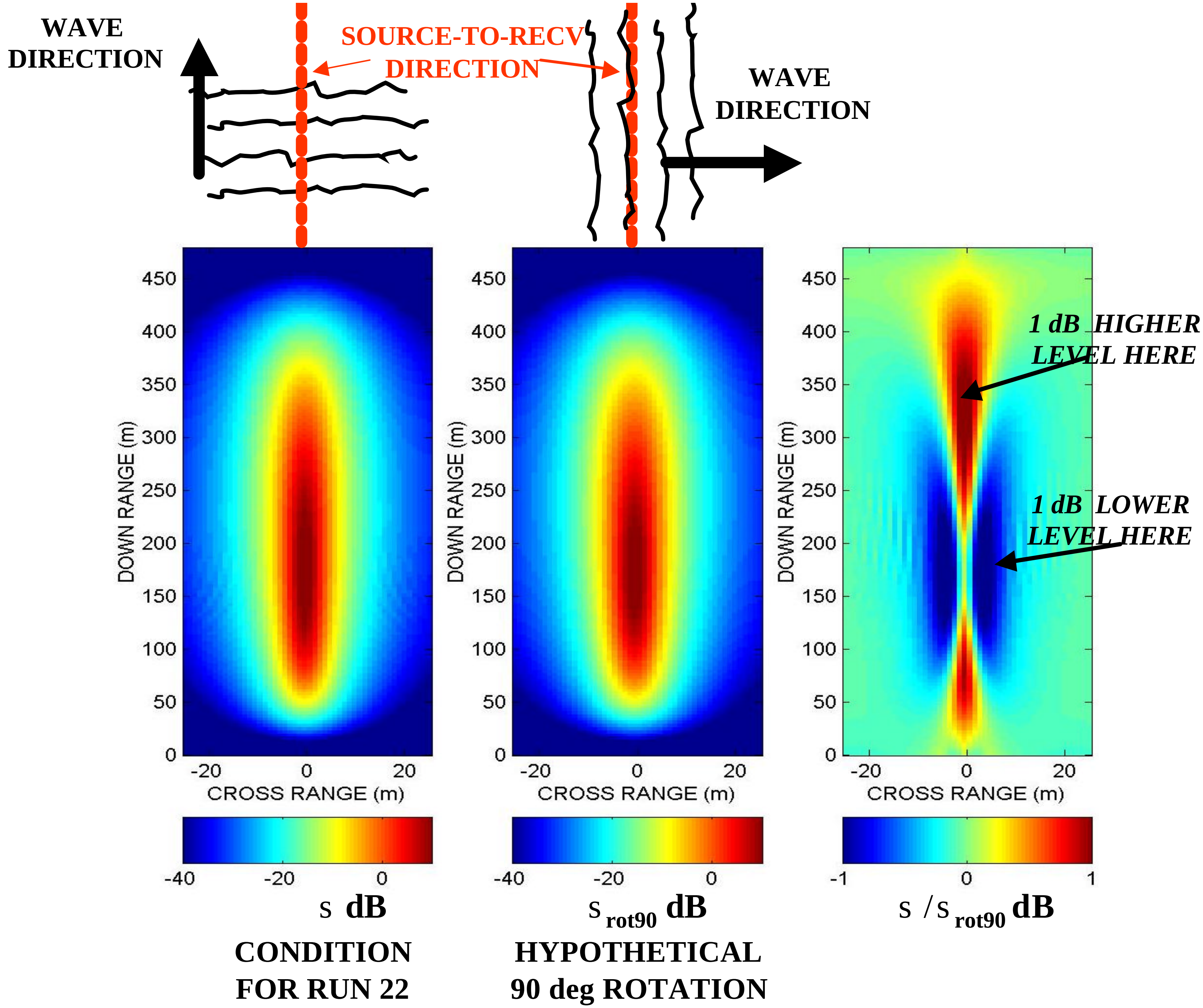


HORIZ COH

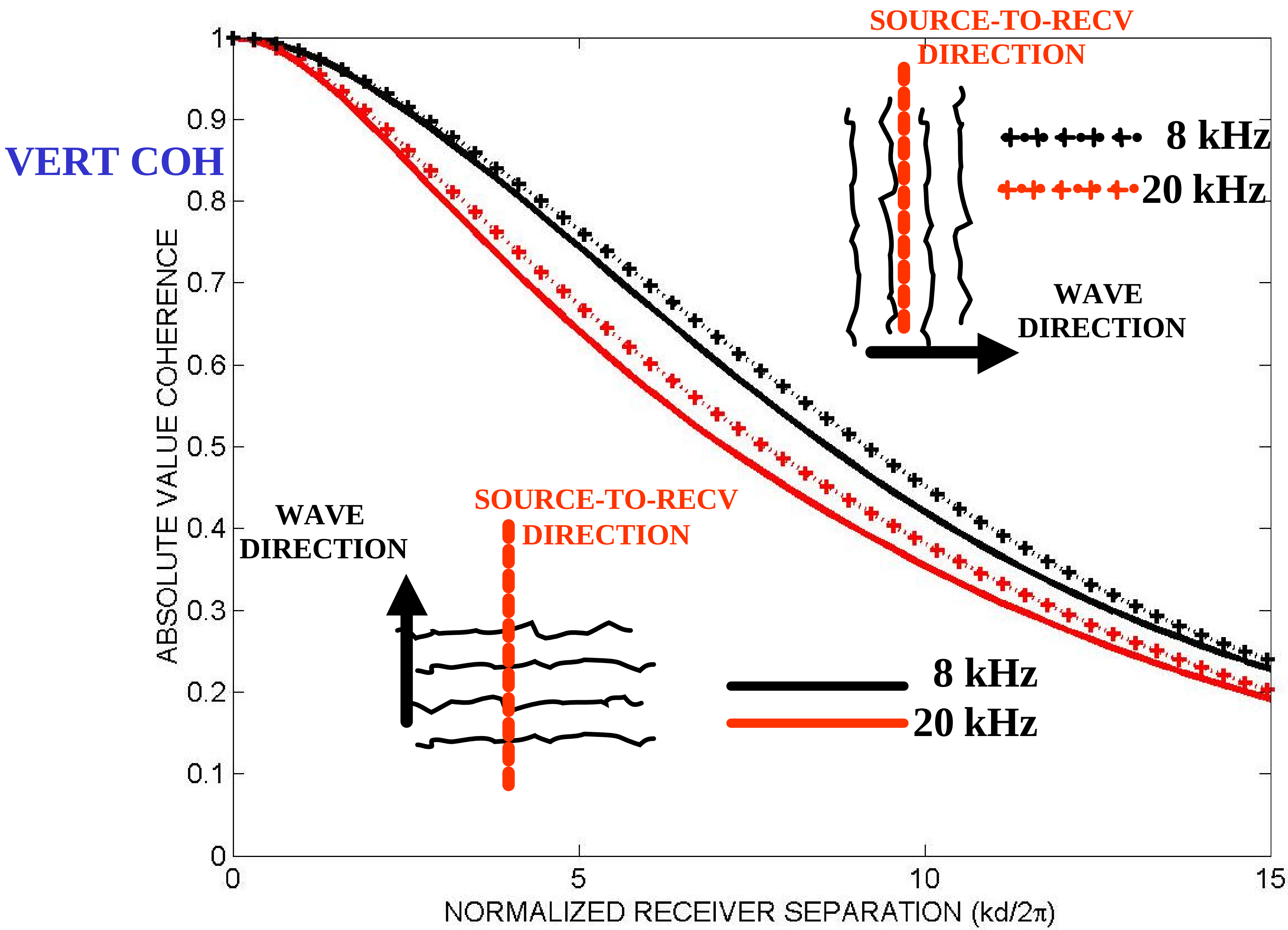
Run22: 5-31 2000 UTC

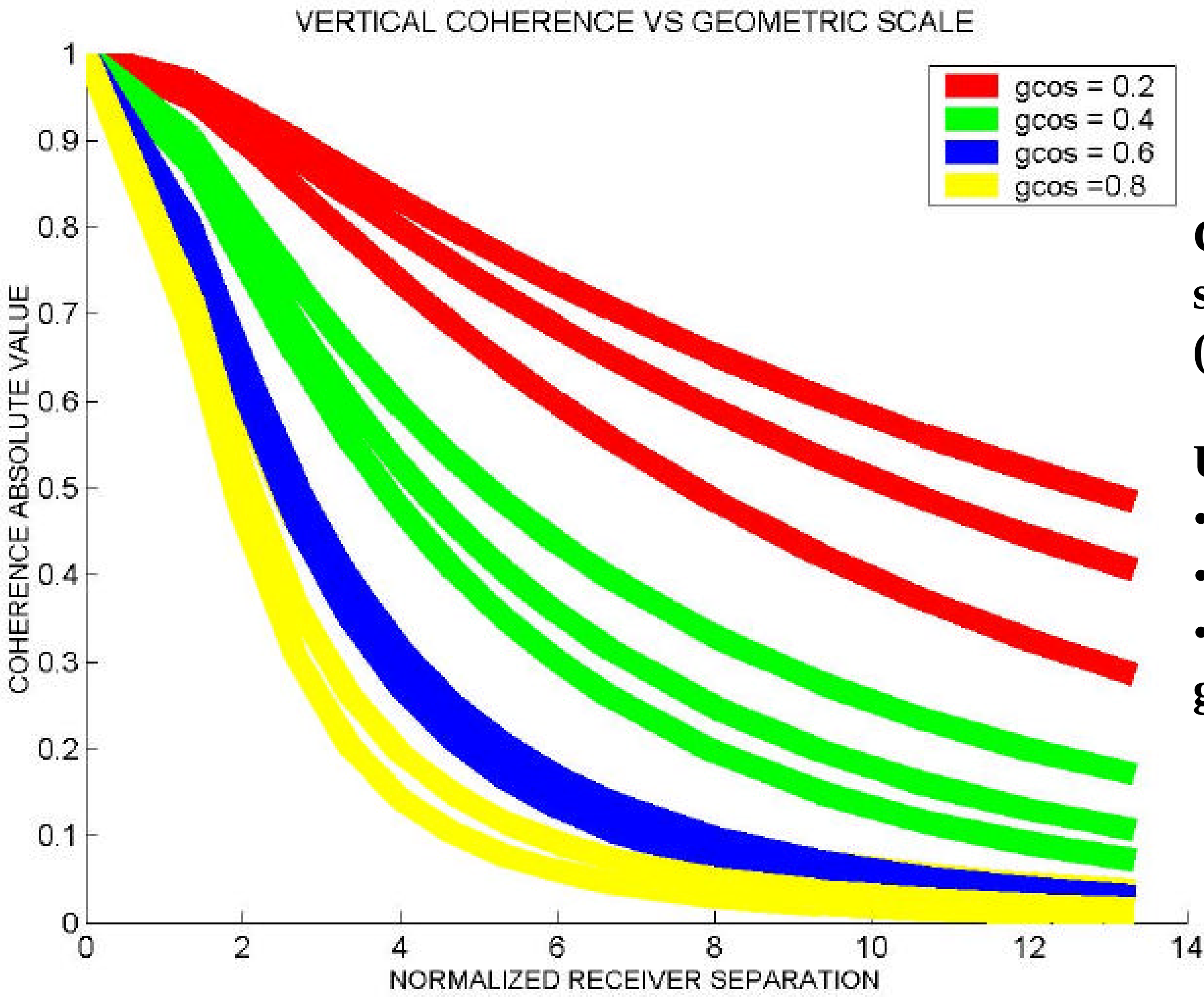
SD 26 m, RD 52, Rg 481 m
U=4 m/s H=0.24 m

8 kHz MODEL, DATA
20 kHz MODEL, DATA
20 kHz ISO SPEED MODEL


WAVE DIRECTION
SOURCE-TO-RECV DIRECTION
WAVE DIRECTION
DOWN RANGE (m)
CROSS RANGE (m)
1 dB HIGHER LEVEL HERE
1 dB LOWER LEVEL HERE
S dB
S rot90 dB
S / S rot90 dB
CONDITION FOR RUN 22
HYPOTHETICAL 90 deg ROTATION

INFLUENCE OF WAVE DIRECTIVITY





Compute model at 20 kHz, same environmental condition (U = 7 m/s)

Use:

- **ranges: 400-700 m**
- **src, rcvr depths: 10-100 m**
- **match the parameter**

gcos = $$\frac{\cos q_g}{1 + RD/SD}$$

SUMMARY Part A: Sea Surface

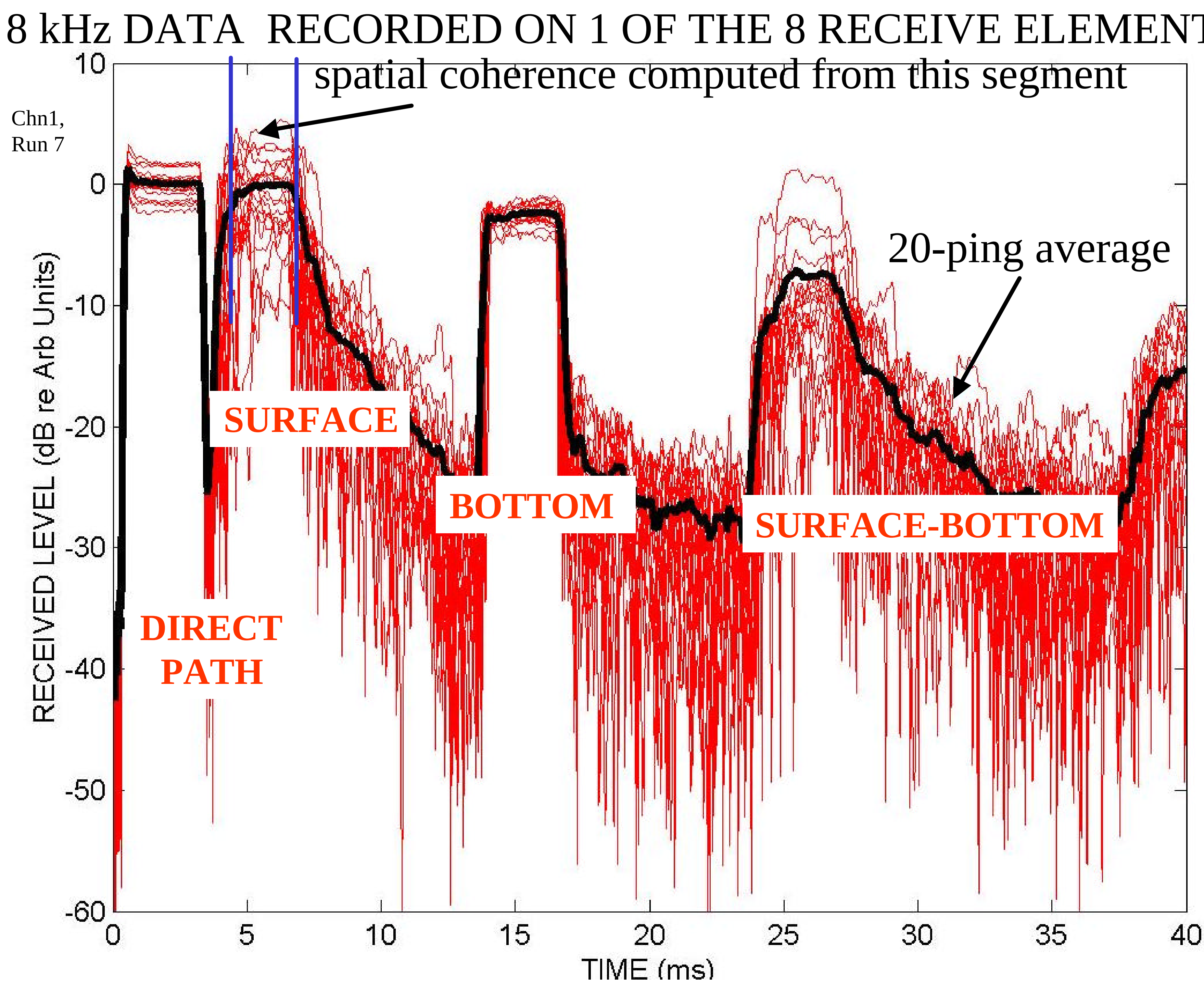
1. Frequency dependence (8 & 20 kHz) observed
in both data and modeling: ↑ spatial coherence for ↓ frequency

2. Effects of downward refraction and surface wave directivity:
both effects small & hard to see, due to high variance in data
(Future: try to combine sets, reduce variance)

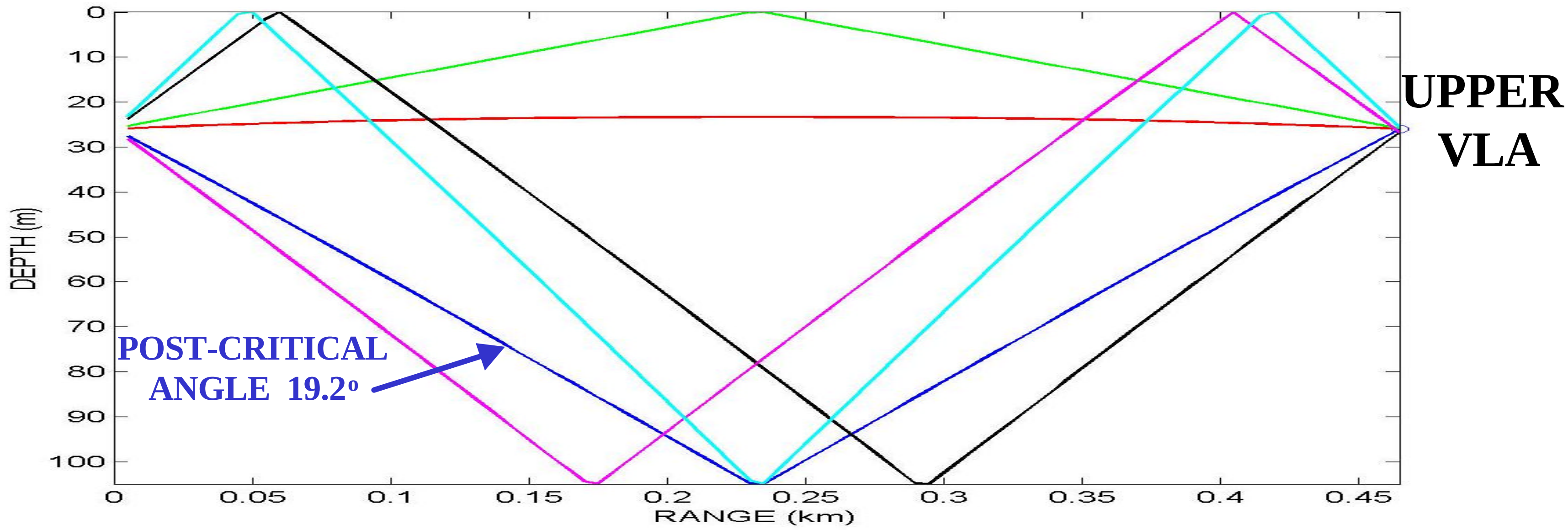
3. Influence geometric scaling parameters for H & V coherence

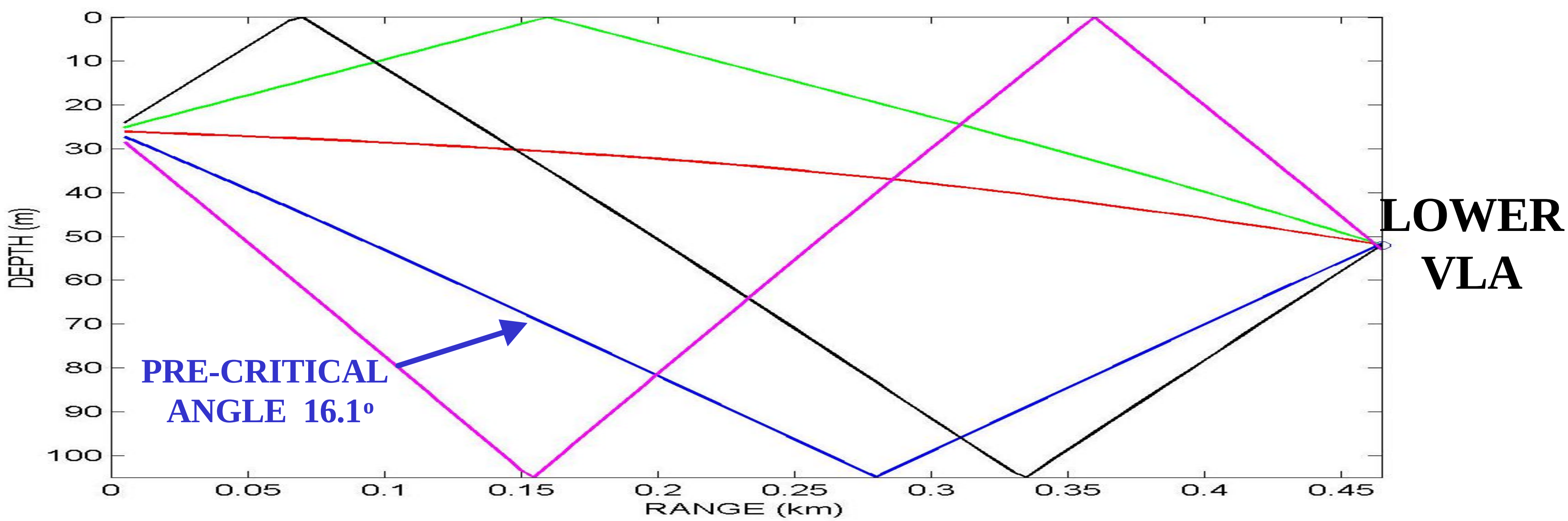
H: $\dfrac{sinq_g}{1+RD/SD}$ V: $\dfrac{cosq_g}{1+RD/SD}$

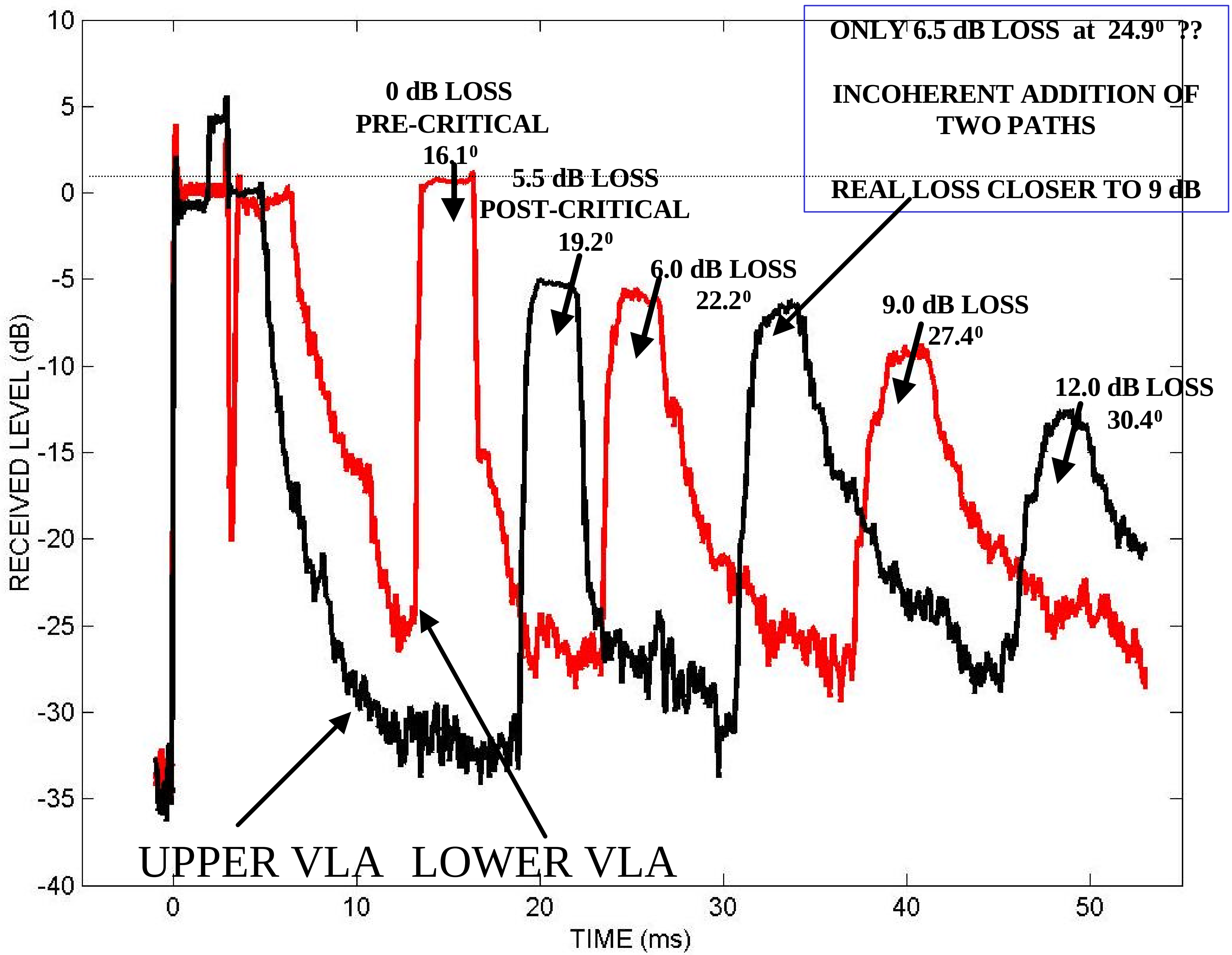
4. Heading towards a predictive model for H & V spatial coherence
in the sea surface bounce path, as needed for communication, imaging and
detection. Today: can do better for > 10 kHz. Challenge is for < 10 kHz
or smaller roughness parameter $c = kH(sinq_i + sinq_s)$


8 kHz DATA RECORDED ON 1 OF THE 8 RECEIVE ELEMENTS
spatial coherence computed from this segment
Chn1,
Run 7
20-ping average
SURFACE
BOTTOM
SURFACE-BOTTOM
DIRECT
PATH
RECEIVED LEVEL (dB re Arb Units)
TIME (ms)
10
0
-10
-20
-30
-40
-50
-60
0
5
10
15
20
25
30
35
40

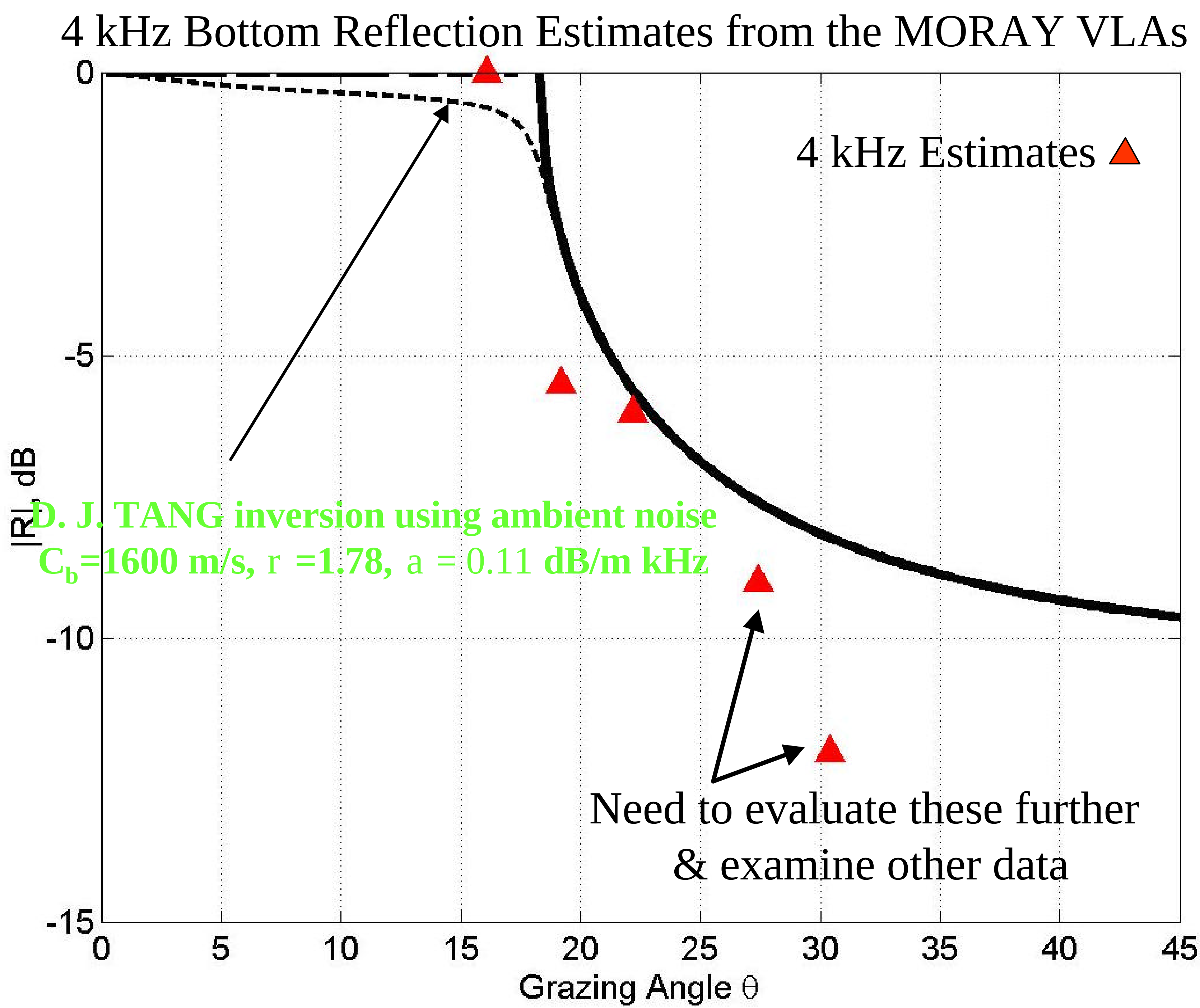
Spanning pre-to-post critical in bottom grazing angles

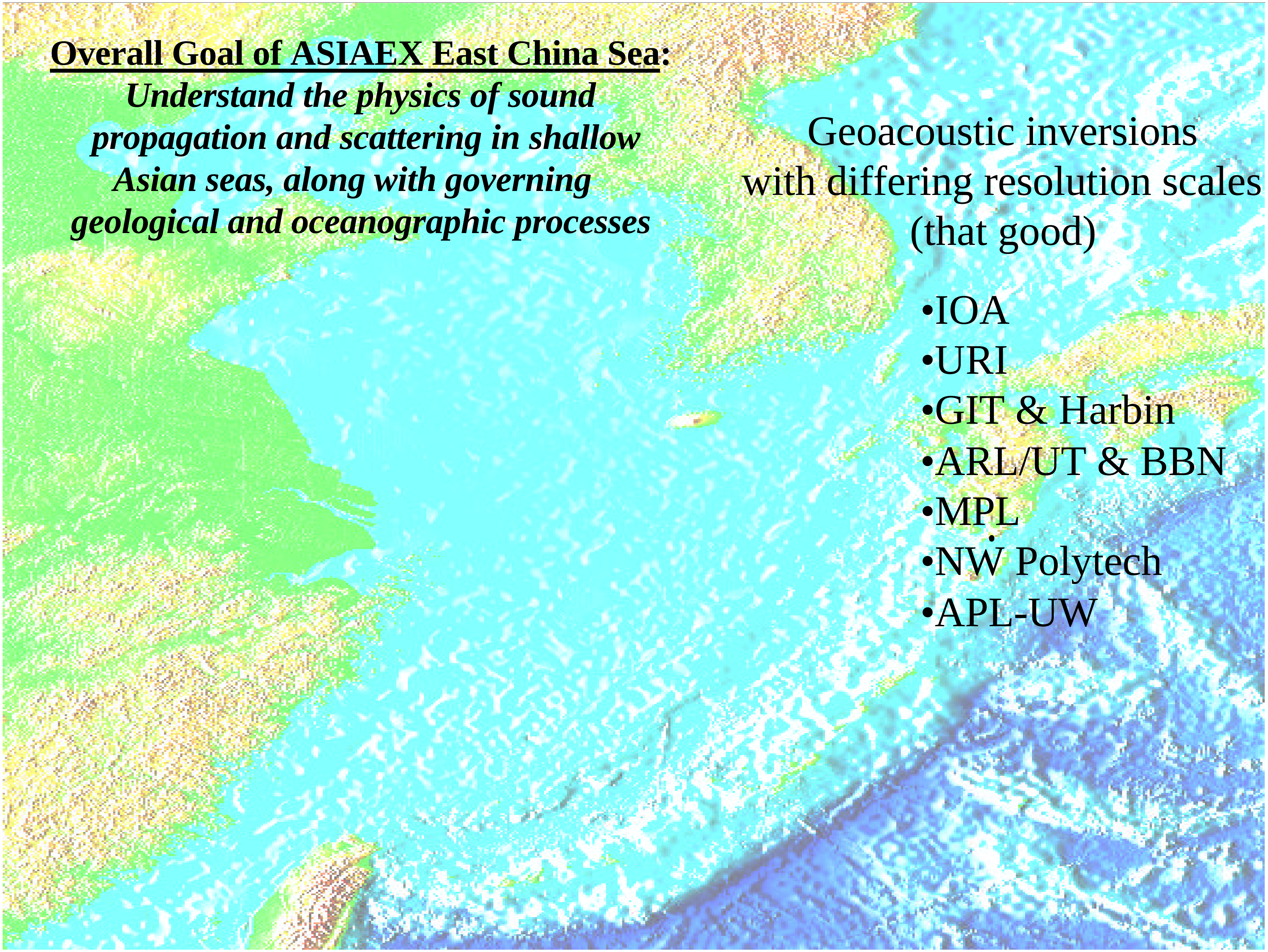






ONLY 6.5 dB LOSS at 24.9⁰ ??
INCOHERENT ADDITION OF TWO PATHS
REAL LOSS CLOSER TO 9 dB
0 dB LOSS
PRE-CRITICAL
16.1⁰
5.5 dB LOSS
POST-CRITICAL
19.2⁰
6.0 dB LOSS
22.2⁰
9.0 dB LOSS
27.4⁰
12.0 dB LOSS
30.4⁰
UPPER VLA
LOWER VLA
RECEIVED LEVEL (dB)
TIME (ms)
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0
10
20
30
40
50


4 kHz Bottom Reflection Estimates from the MORAY VLAs
4 kHz Estimates
D. J. TANG inversion using ambient noise
Cb=1600 m/s, r =1.78, a = 0.11 dB/m kHz
Need to evaluate these further
& examine other data
|R|, dB
Grazing Angle θ
0
-5
-10
-15
0
5
10
15
20
25
30
35
40
45



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Understand the physics of sound propagation and scattering in shallow Asian seas, along with governing geological and oceanographic processes

Geoacoustic inversions
with differing resolution scales
(that good)

- IOA
- URI
- GIT & Harbin
- ARL/UT & BBN
- MPL
- NW Polytech
- APL-UW

<u>Overall Goal of ASIAEX East China Sea</u>:

Understand the physics of sound propagation and scattering in shallow Asian seas, along with governing geological and oceanographic processes

<u>Short Term (and achievable) Goal:</u>

A unified geoacoustic model for at least:

- "Position M" in the East China Sea,

followed by:

(2) The general ECS region of "our box"

Long Term Goal:

Towards an atlas of geoacoustic models For the Asian Littoral

Geoacoustic inversions with differing resolution scales (that good)

- IOA
- URI
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- MPL
- NW Polytech
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